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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 :
G01D 5/30, 5/34

A1

(11) International Publication Number: WO 89/ 02064

(43) International Publication Date: 9 March 1989 (09.03.89)

(21) International Application Number: PCT/US88/02733

(22) International Filing Date: 8 August 1988 (08.08.88)

(31) Priority Application Number: 093,338

(32) Priority Date: 4 September 1987 (04.09.87)

(33) Priority Country: US

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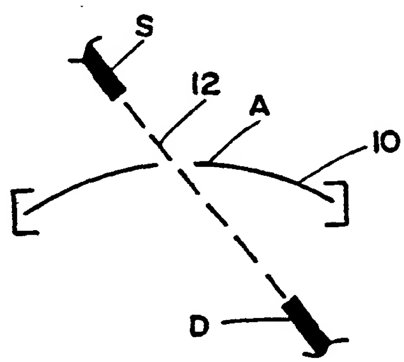
(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent).

Published
With international search report.

(54) Title: FIBER OPTIC THERMAL SWITCH



(57) Abstract

A fiber optic thermal switch is described comprising a first fixed fiber optic element (S) for transmitting light from a source of light, a second fixed fiber optic element (D) for transmitting light emitted from the first fiber optic element (S) and a snap-acting element (10), disposed between the ends of each fiber optic element (S, D), for interrupting the path of light flowing between the two fiber optic elements (S, D) in response to a change in temperature. In one specific embodiment, the snap-acting element (10) is in the form of a bimetallic disk (10) which changes its shape from a concave shape to a convex shape in response to a temperature change above a generally fixed transition temperature.

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FIBER OPTIC THERMAL SWITCH

Field of Invention

This invention relates, in general, to the subject of switching mechanism and fiber optics. In particular, this invention relates to an apparatus and method for rapidly opening or closing a light path between two optical fibers in response to a change in temperature.

Background of the Invention

For many years, Sundstrand Data Control has produced a snap-acting thermal switch to control the flow of electricity between two terminals in response to a temperature change. In particular, that thermal switch used a specially-processed bimetallic disk which is temperature sensitive. As its temperature increased to a precalibrated set point, the disk would snap from a concave to a convex shape and, in the process, move a striker pin to open or close a set of contacts. As the temperature decreased below that set point, the disk would snap back to its original shape and return the contacts to their original state. The switch, of course, could be designed to open or close the contacts in response to an increasing or decreasing temperature. One specific product is the 570-Series switch. This switch is military qualified, has a SPST contact arrangement, has a temperature set point range between -80° to $+630^{\circ}$ Fahrenheit and has a dielectric withstand voltage of 1,500 volts RMS. Because of the simplicity of design,

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it has many applications. For example, bearing overheating and warning, electronic compartment control, duct air temperature control, hydraulic overhead protection, motor pump over temperature protection and battery temperature control, to name a few.

While this snap-acting switch has proven to be a very successful and highly reliable design, a purely mechanical/electrical switch has some shortcomings. By contrast, optical or fiber optic switches have advantages in terms of size, weight, freedom from electromagnetic interference, and freedom from the effects of EMP (the Electro Magnetic Pulse, from nuclear radiation following an atomic blast) and related interference. Fiber optics systems also offer cost savings due to their inherent simplicity. Moreover, there is improved temperature stability, reduced contamination problems, and reduced propensity to creep. Finally, certain problems are eliminated because device is non-electrical (i.e., contact resistance and contact wear). Therefore, a snap-acting thermal switch which, instead of controlling the flow of electrical current between two terminals, controls the flow of light between two fiber optic elements, is a device which has advantages. Moreover, if the device was compatible with digital control circuits, it would be eagerly accepted by the marketplace.

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Summary of the Invention

In accordance with the present invention, a fiber optic thermal switch is provided comprising: a first fixed fiber optic element for transmitting light from a source of light; a second fixed fiber optic element for transmitting light emitted from the first fiber optic element; and a snap-acting device, which is disposed between the two fiber optic elements, for rapidly interrupting or establishing the path of light emitted from the first fiber optic element and directed toward the second fiber optic element in response to a change in temperature. In the basic embodiment, the snap-acting means comprises a bimetallic element having one position when its temperature is below (for example) a transition temperature and a second position when it is above the transition temperature. This bimetallic element is preferably cup-shaped so as to change either from a convex shape to a concave shape or to a concave shape from a convex shape depending on the temperature change.

In one embodiment, the snap-acting element is provided with a reflective surface for reflecting light between the two fiber optic elements such that when the temperature changes above (for example) the transition temperature, the reflective surface is displaced and the light path is interrupted. In still another embodiment, the snap-acting element comprises a substantial non-opaque bimetallic element having an aperature therein

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such that when the bimetallic element is in one position, the aperature is disposed between each fiber optic element and when the temperature changes is above (for example) the transition temperature, the light path is interrupted or blocked.

In one particularly novel embodiment, the snap-acting element comprises a filter adapted to remove one specific wavelength (i.e., color) of light and a means for placing the filter into the path of light between the two fiber optic elements. Therefore, when the second fiber optic element is connected to a light sensor which is sensitive to the wavelength of light, that sensor has an output which is a function of temperature.

In a final embodiment, the snap-acting element comprises a light shutter disposed in the disk aperature with the shutter defining a plurality of light transmissive elements, whereby when the temperature changes, a plurality of coded light pulses is transmitted to the second fiber optic element.

Numerous other advantages and features of the present invention will be readily apparent from the following detailed description of the invention, its various embodiments, from the claims and from the accompanying drawings.

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Brief Description of the Drawings

FIG 1 and 1A are pictorial representations of one embodiment of the invention;

FIG's 2 and 2A are diagramatic representations of a second embodiment of the invention;

FIG's 3 and 3A are diagramatic representations of a third embodiment of the invention;

FIG's 4A, 4B, 4C, 4D, and 4E are diagramatic representations of still another embodiment of the invention;

FIG 5A is a diagramatic representation of two snap-acting thermal switches of the type illustrated in FIG's 3A and 3B;

FIG's 5B and 5C represent still another embodiment of the invention;

FIG's 6A, 6B, and 6C illustrate an embodiment of the invention somewhat similar to that embodiment covered in FIG's 1 and 1A; and

FIG's 7, 7B, and 7C illustrate an embodiment of the invention somewhat similar to that illustrated in FIG's 2 and 2A.

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Detailed Description of the Preferred Embodiments

While this invention is a susceptible embodiment in many different forms, there is shown in the drawings and will herein be described in detail, several preferred embodiments of the invention. It should be understood, however, that the present disclosure is to be considered an exemplification of the principals of the invention and is not intended to limit the invention to the specific embodiments illustrated.

It should be understood throughout the description which follows that the terms "concave" and "convex" are relative to a specific reference or point of observation. Moreover, with respect to the transition temperature of a snap-acting bimetallic element, that element can change its shape from a convex to a concave shape depending on whether or not a temperature increases above a predetermined set point or a temperature decreases below a predetermined set point. Thus, the particular configuration shown in the drawings are for purposes of illustration and not intended to be limited to the specific transitions and shape changes so illustrated. Once the principles of the invention are understood, the generality of the apparatus will be appreciated.

Turning to the drawings, FIG 1 depicts one basic

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embodiment of the invention. In particular, there is illustrated one end of a fiber optic element S which is adapted to be connected to the source of light, a second fiber optic element D which is adapted to be connected to a detector, for example, and a bimetallic generally convex shaped snap-acting disk 10. As shown as FIG 1, the surface of the disk is finished so as to reflect light emitted from the fiber optic element S connected to the source of light in the direction of the fiber optic element D connected to the detector.

The disk 10 may be fabricated from a bimetallic strip. Sundstrand Data Control of Redmond, Washington, has used such a disk in regard to its precision snap-acting thermal switch product line. GTE Sullvania, Texas Instruments, and other manufacturers produce bimetallic disks from a polymetallurgical material. In the case of a bimetallic element, differential expansion of the two metals will cause the disk to change shape from one curvature to another when the temperature changes above or below a defined transmission temperature. In the case of the embodiment illustrated in FIG 1, the disk 10 changes from a convex shape to a concave shape (see FIG 1A) when the temperature changes. For example, the temperature could increase in changing from convex to concave or the temperature can decrease in changing from convex to concave. Those skilled in the art are familiar with how such devices may be manufactured and how the transmission set point may be selected.

Materials currently used by Sundstrand Data Control allow disks to the manufactured which can sense temperature changes from the cyrogenic range to about 700^{o} Fahrenheit. Snap-acting disk elements can be made as small as 0.1 inches to as large as 2 or more inches in diameter.

Returning to FIG 1A, it should be understood that when the disk changes from the convex shape (see FIG 1) to the concave shape, the light emitted from the source S and reflected from the disk 10 will miss the second fiber optic element D, thereby rapidly interrupting the transmission of light between the source and the detector connected to each of the two fiber optic elements. Since the disk changes shape quite rapidly, the light flowing to the detection D is interrupted or broken. Thus, in effect, the temperature change using the mechanism illustrated in FIG 1, is effectively transformed into a light signal which is either on or off and is easily processed by digital equipment.

The effectiveness of the switch shown in FIG's 1 and 1A can be enhanced by limiting the size of the reflective Area on the disk and its location. Also, by adding light absorbing materials in areas not intended to be reflective, the amount of scattered light can be reduced.

Turning to FIG's 2 and 2A, another embodiment of the invention is illustrated. In particular, an aperature is provided in the disk 10 and the two fiber optic elements S and D are aligned so that light emitted from one of the elements passes directly to the second element after passing through the aperature in the disk. Thus, when the temperature of the disk changes relative above its transition temperature, the path of light 12 will be rapidly broken (see FIG 2A). Again, we have the effect of rapidly interrupting the path of light and providing a signal in response to a change of temperature.

The embodiment shown in FIG's 3 and 3A represents another variation of the principal exemplified in the embodiment of FIGs 2 and 2A. Specifically, the disk 10 is provided with a shutter 18 to block the path between the two fiber optic elements. Thus, when the shutter 18 is between the two fiber optic elements (see FIG 3), the light emitted by the first fiber optic element S is blocked and absorbed or reflected away from the second fiber optic element D. However, when the temperature of the fiber optic disk changes above the transition temperature, shutter 18 is moved out of the way and light is free to pass between the two fiber optic elements (see FIG 3A).

Turning now to FIG's 4A, 4B, and 4C, that embodiment also features a shutter. This shutter 20' is partially opaque so as to define a plurality of light

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interrupting and light transmissive elements or bars. Thus, when the disk 10' (see FIG 4A) is at one temperature T1 such that the shutter 20' is displaced out of the path between two fiber optic elements S and D, light is free to pass between the two fiber optic elements. However, when the temperature changes from T1 to T2 above the transition temperature of disk, the shutter 20' is rapidly inserted into the light path 12 between the two fiber optic elements. Since the shutter has both light transmitting and light interrupting portions, the light passing to second fiber optic element is transmitted in accordance with the pattern formed on the shutter 20' (see the upper right hand corner of FIG 4B). Thus, a specific coded light pattern can be produced in response to a temperature change. For example, a plurality of optical switches such as that shown in FIG's 4A and 4B can be connected together such that a common detector is used. Since each disk will change temperature at a specific set point and each has a different shutter, the coded light pattern sensed by the protector will provide a representation of the temperature change.

FIG's 4D and 4E illustrate a generally elongated shutter 20" with a longer set of light interrupting elements. Thus, the shutter 20" need not be totally removed from the path between the two fiber optic elements S and D. In other words, the strip between the shutter 20" can be configured so as to provide a coded light pattern whether or not it was removed from the path

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between the two fiber optic elements. This embodiment would be particularly useful if a creep type temperature sensor is used instead of the bimetallic disk. The disadvantage of using a coded shutter that the sensor connected to the second fiber optic element S would have to operate continuously (i.e., not strobed).

Turning to FIG 5C, there is illustrated a bimetallic disk 10 carrying a light filter 24. The light filter, as the name implies, filters, removes, or passes light of a limited frequency or band when a ray of light is directed at the filter.

It should be understood with regard to the discussion of "color" which follows, that color is a visually perceptible characteristic of visible light. Light is characterized by its frequency or wavelength and includes ultra-violet (UV) and infra-red (IR) radiation. Thus, a filter may be used which passes UV or IR light and not visible light, for example.

In FIG 5A, two snap-acting fiber optic switches using the disk and filter of FIG 5C are connected in series. In particular, coupling C is used to connect one fiber optic element D1 of one switch to the fiber optic element S2 of the second switch. Thus, when the temperature of the two switches is below the transition temperature wherein the bimetallic elements 10 and 11 change from a concave shape to a convex shape, the path of light flows between the first fiber optic elements of

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the first switch to the second fiber optic element D2 of the second switch. If the temperature of the first switch reaches above its transition temperature, the filter 24 of that switch would filter the light flowing between its light source and detector. For example, as the temperature increased above the transition temperature of the first switch, the first filter 24 could remove red light from the light source. As the temperature increased further, the second filter 25 would block the path of light (see FIG 5B) and another color would be removed from the light beam. Thus, by using a light sensor which is sensitive to the color of light, the output of that sensor would be a direct function of the position of the disks and the temperature of those disks.

Turning now to FIG's 6A, 6B, and 6C, we have an embodiment which is somewhat similar to that embodiment shown in FIG's 1 and 1A. Specifically, that area of the disk A which is used to reflect light between the two fiber optic elements S and D is provided with a series of light reflecting and light absorbing elements such that when the disk changes from one configuration (see FIG 6A) to its other configuration (see FIG 6B) the light is alternatively interrupted and passed between the two fiber optic elements such that a coded pattern is produced (see the upper right hand corner of FIG 6B). A lens L may be used to columnate the light reflected from disk 10. This embodiment suffers from the same disadvantage of the embodiment shown if FIG 4A through 4E (i.e., continuous sensor energization is required).

Finally, turning to FIG 7C, there is illustrated a disk 10 which is provided with a shutter-like aperature of alternating light transmissive and light blocking elements. Thus, when such a disk is used with regard to the basic embodiment shown in FIG's 2A and 2B, the disk 10 when changing from one configuration (see FIG 7A) to another (see FIG 7B) will produce a coded light pattern or a series of pulses (see the lower right hand corner of FIG 7B). This embodiment also has the disadvantage of that shown in FIG's 4A through 4E.

From the foregoing, it should be noted that numerous variations and modifications may be affected without departing from the true spirit and scope of novel concept of the invention. For example, the snap-acting elements need not be confined to bimetallic elements. "Creep" type temperature sensitive materials can also be used to trip spring loaded devices (such as those used in microswitches). When such a device is used, temperature of the materials can be exploited that are beyond the capability of present bimetallic technology. Thus, it should be understood that no limitation with respect to the specific embodiment illustrated is intended or should be inferred. It is, of course, intended to cover by the appended claims all such modifications that fall within the scope of the claims.

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CLAIMS

I Claim:

1. Apparatus, comprising:

(a) a first fixed fiber optic element for transmitting light from a source of light;

(b) a second fixed fiber optic element for transmitting light emitted from said first fiber optic element, said second fiber optic element having an end disposed at a spaced distance from one end of said first fiber optic element; and

(c) snap-acting means, disposed between said first fiber optic element and said second fiber optic element, for interrupting the path of said light in response to a change in temperature.

2. The apparatus set forth in Claim 1, wherein said snap-acting means comprises a bimetal having one position when its temperature is below a transition temperature and a second position when it is above said transition temperature.

3. The apparatus of Claim 2, wherein said bimetal changes from a convex shape to a concave shape when the temperature changes from one side of said transition temperature to the other side of said transition temperature.

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4. The apparatus as set forth in Claim 1, wherein said snap-acting means comprises reflector means for reflecting light from said one end of said first fiber element to said one end of said second fiber element when the temperature is on one side of a predetermined transition temperature, whereby said path defines a broken line segment.

5. The apparatus as set forth in Claim 1, wherein said snap-acting means comprises a substantially non-opaque bimetallic element having one position when said temperature is on one side of a predetermined transition temperature and a second position when said temperature is on the other side of said transition temperature, said bimetallic element having an aperture therein such that when said bimetallic element is in said one position said aperture is disposed between said one end of said first fiber optic element and said one end of said second fiber element said ray of light passes through said aperture, and wherein said ray of light is blocked when said bimetallic element is in said second position.

6. The apparatus as set forth in Claim 1, wherein:

said light source comprises a plurality of colors; and

said snap-acting means comprises a filter adapted to remove one color of light, and means for placing said filter into the path of said light in response to the temperature increasing above a first transition temperature.

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7. The apparatus set forth in Claim 6 wherein said second fiber optic element is adapted to be connected to a light sensor which is sensitive to the wavelength of light.

8. The apparatus as set forth in Claim 7, further including:

(a) another filter adapted to remove another wavelength of light; and

(b) means for placing said another filter into the path of said light in response to the ambient temperature increasing above a second transition temperature, whereby the wavelength of light sensed by said light sensor is a function of the ambient temperature relative to said first transition temperature and said second transition temperature.

9. The apparatus as set forth in Claim 4, wherein said reflector means comprises a plurality of light reflective elements defining a coded pattern, whereby when said temperature changes to said one side of said transition temperature, a plurality of coded light pulses is received by said second fiber optic element.

10. The apparatus as set forth in Claim 1, wherein said snap-acting means comprises a light shutter disposed in said aperature, and wherein said shutter defines a plurality of light transmissive elements, whereby when said temperature changes, a plurality of coded light pulses is received by said sensor.

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11. The apparatus as set forth in Claim 1, wherein said light source emanates from the end of a fiber optical transmission line.

12. The apparatus as set forth in Claim 11, wherein said second fiber optic element comprises an optical fiber aligned to transmit light emanating from said fiber optical transmission line.

13. A method for providing a digital signal representative of a change of temperature comprising the steps of:

(a) providing a first fiber optic line for transmitting light from a source to one end of an optical fiber;

(b) providing a second fiber optic line for transmitting light to a sensor which is responsive to light, said second line having one end which is located in a position relative to said one end of said first fiber optic line so as to receive light emitted from said one end of said first fiber optic line; and

(c) rapidly interrupting light emitted from said one end of said first fiber optic line and passing to said one end of said second fiber optic line in response to the ambient temperature changing above a preselected value, said light being rapidly interrupted by using a snap-acting element and light path changing means which is disposed between said one end of said first fiber and said one end of said second fiber and which is carried by said snap-acting means.

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14. The method of Claim 13, wherein said snap-acting element is a bimetallic disk.

15 The method set forth in Claim 13, wherein said light path changing means blocks light of at least one frequency.

16. The method set forth in Claim 13, wherein said light path changing means is positioned to block the path of light from said first fiber optic line to said second fiber optic line when the temperature of said snap-acting element is above a preselected value.

17. The method set forth in Claim 13, wherein said light path changing means reflects light from said one end of said first fiber optic line to said one end of said second fiber optic line when the temperature of said snap-acting element is below said preselected temperature.

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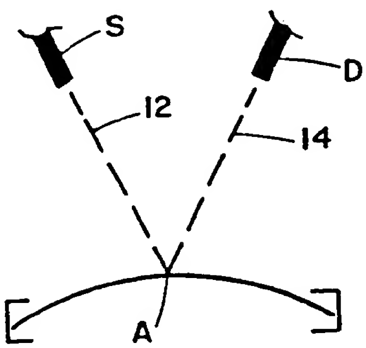

FIG. 1

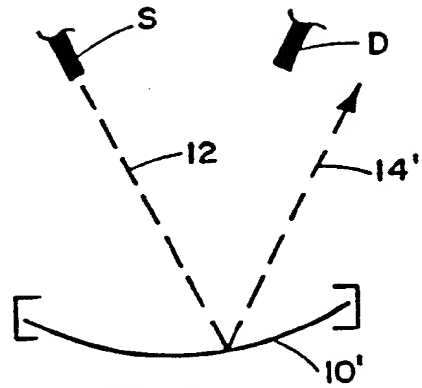

FIG. 1A

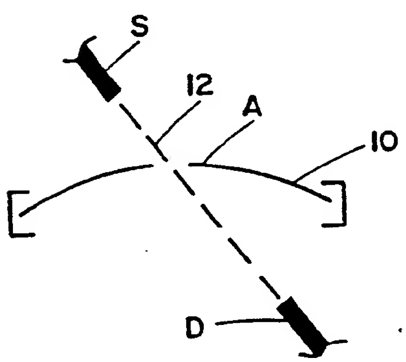

FIG. 2

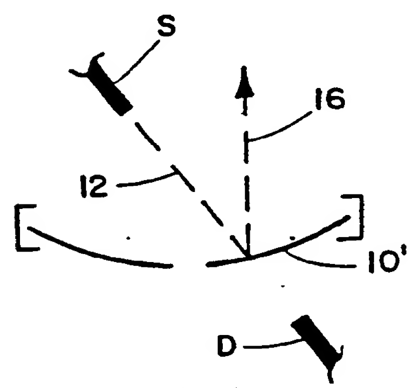

FIG. 2A

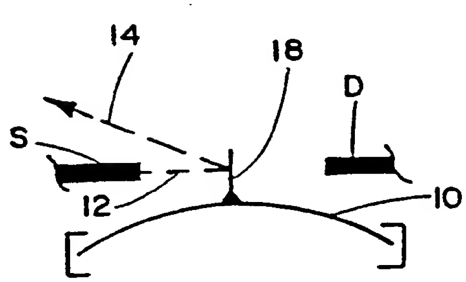

FIG. 3

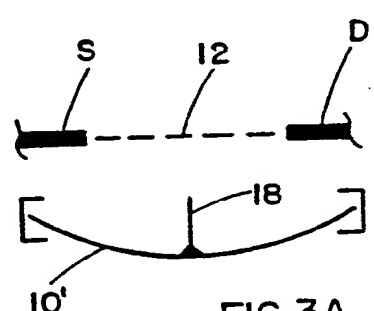

FIG. 3A

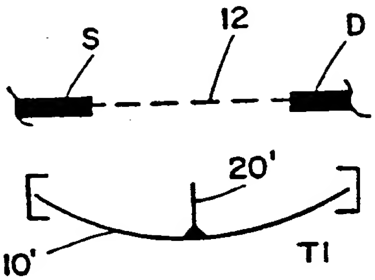

FIG. 4A

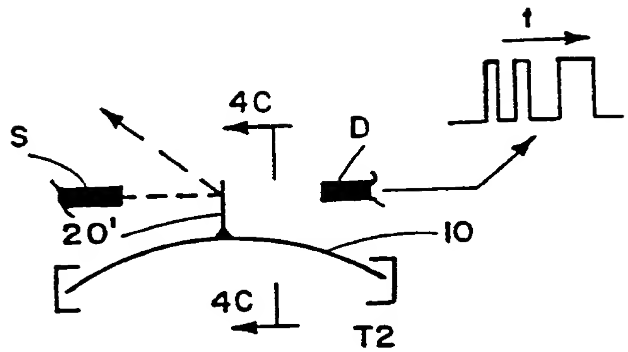

FIG. 4B

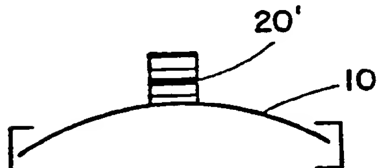

FIG. 4C

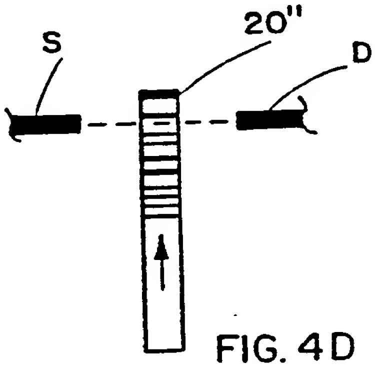

FIG. 4D

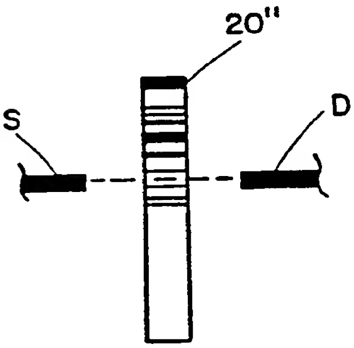

FIG. 4E

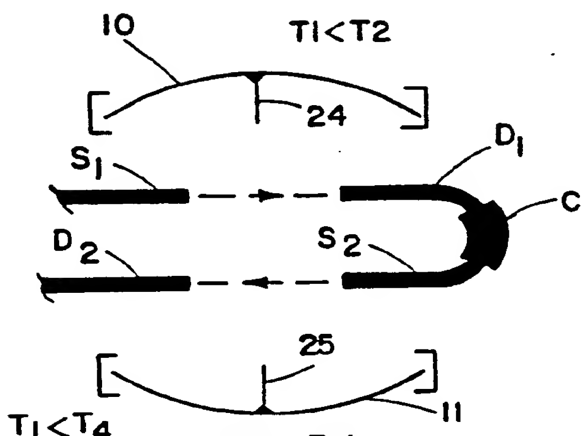

FIG. 5A

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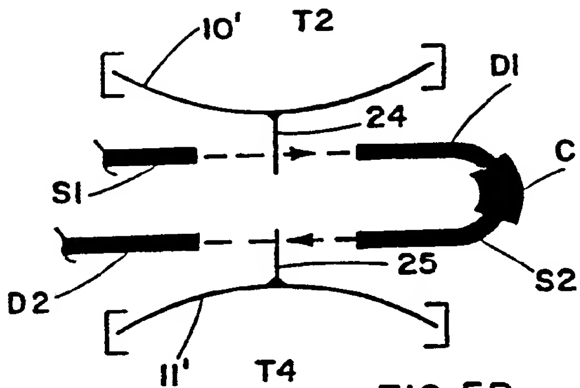

FIG. 5B

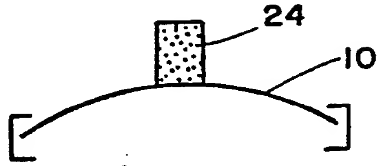

FIG. 5C

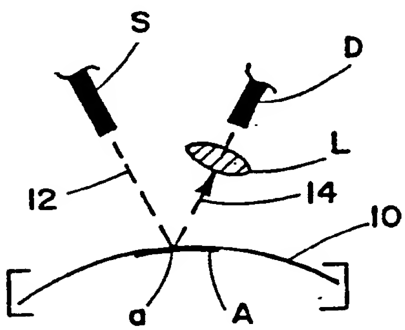

FIG. 6A

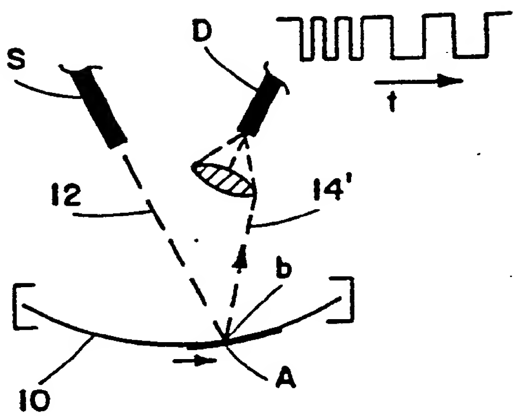

FIG. 6B

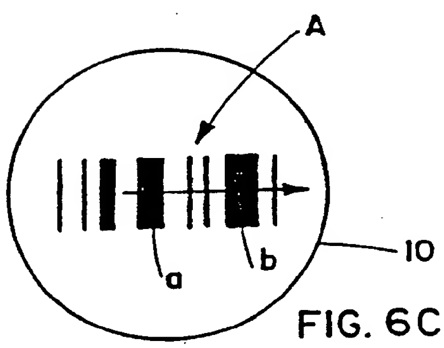

FIG. 6C

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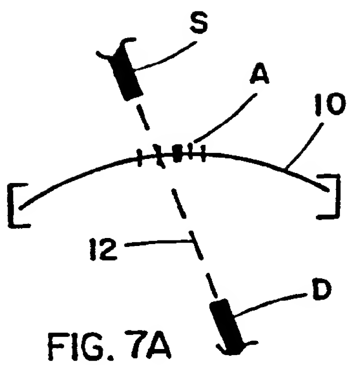

FIG. 7A

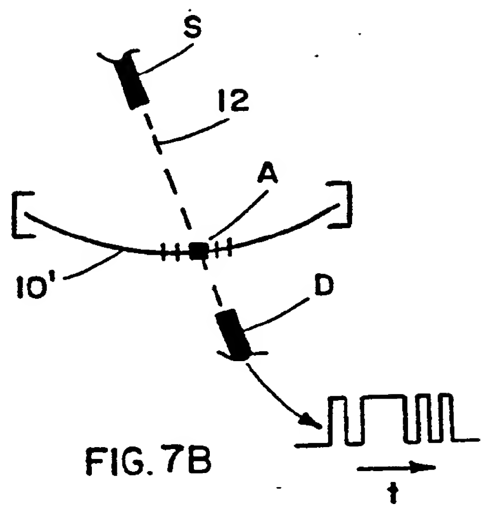

FIG. 7B

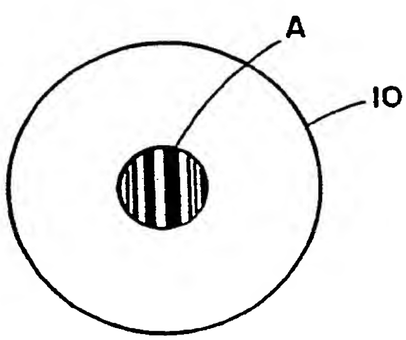

FIG. 7C

BNSDOCID: <WO___8902064A1_I_>

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US88/02733

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: G01D 5/30; G01D 5/34
U.S. Class: 250/231R, 226,227

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S.	250/227, 231R, 231P, 226, 229, 221 73/705, 715; 374/159, 161, 162

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	US, A, 3,796,393, (BEISTLE) 12 March 1974	
A	US, A, 3,898,454, (FRIDAY et al) 05 August 1975	
A	US, A, 4,464,936, (McIntire et al) 14 August 1984	
X	US, A, 4,521,683, (MILLER) 04 June 1985 See column 3, line 62 to column 6, line 37	1-17
Y	US, A, 4,543,961, (BROWN) 01 October 1985 See column 3, line 62 to column 4, line 10	6-8,15
A	US, A, 4,588,886 (SNIDER) 05 May 1986	
A	US, A, 4,611,600 (COHEN) 16 September 1986	

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
28 October 1988	09 DEC 1988
International Searching Authority	**Signature of Authorized Officer**
ISA/US	Edward P. Westin Edward P. Westin